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16. ABSTRACT

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Technique for Removal of Dissolved and Dispersed Hydrocarbons from Bioassay Effluents

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JOURNAL ARTICLE

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■ A method for the efficient removal of petroleum-derived hydrocarbons from the oil-contaminated effluent of a continuous flow-through oil bioassay system is described. The concentration of No. 2 fuel oil in the effluent, discharged at rates from 17 to 26 L/min, is reduced from an average of 17 to approximately 1 ppm by passing the water through acrylic fibers.

Laboratory bioassays are often utilized to assess the impact of oil on aquatic organisms. However, the experiments themselves initiate a pollution source, particularly when continuous flow-through techniques are employed. It is necessary then to remove the oil from the bioassay effluent prior to discharging it into the environment.

We have found at the Environmental Research Laboratory that physical separation and removal of insoluble surface oil account for an approximate 80% reduction in the total amount of oil entering a continuous flow-through oil dosing system (*1*). However, the remaining 20% creates a final oil effluent concentration near 17 ppm, and may still be considered harmful to resident organisms in the receiving waters. The following report discusses our filtration technique for the removal of the remaining dissolved and dispersed oil. No. 2 fuel oil was used throughout our experiments.

Methodology and Results

To test the effectiveness of various filter materials, we initially selected three types of woven fiber filter cartridges (Faucett Corp.), each having the same rated pore size (1–7 μm), cartridge length (25 cm), and diameter (6 cm). The cartridges included acrylic (polyacrylonitrile), glass, and viscose rayon. All cartridges were housed in standard filter units (e.g., Fulflo) and were gravity fed the effluent leaving the oil bioassay system. Concentrations of soluble and dispersed hydrocarbons in the effluent prior to filtering ranged from 11 to 16 ppm, as determined by infrared spectrophotometric analysis (*1*). The effectiveness of each filter cartridge in removing oil from the effluent was tested by comparing the prefilter and postfilter hydrocarbon concentrations after 1, 2, 3.5, and 6.5 h (Table I).

The data indicate that the acrylic cartridges are superior to both rayon and glass. Effluent hydrocarbon levels during the acrylic test did not exceed 1 ppm even after 6.5 h of filtering, whereas hydrocarbon levels in the effluents from both the rayon and glass test exceeded 2 ppm within the first hour. Furthermore, the concentration of hydrocarbons in the effluent leaving the acrylic cartridge changed very little with time throughout the test, whereas effluents from both the glass and rayon cartridges showed increasing oil concentrations with time.

The flow of seawater through the acrylic cartridge decreased from 4 L/min at the start of the test to only 0.8 L/min after 6.5 h. In contrast, the flow of seawater through both the rayon and glass cartridges decreased from 4 to 2 L/min during the same time period. All the cartridges tested were of the same pore size and theoretically should have retained the same amount of suspended material from the incoming unfiltered seawater.

The removal of hydrocarbons from seawater by these filters is most likely a combination of retention of oil-laden particles, and active coalescing, retention, and adsorption of oil by the fiber surface. Since all of the cartridges tested should be equally effective in removing suspended particles from the seawater passing through the cartridges, we conclude that the increased efficiency of the acrylic cartridge is a result of the higher oleophilic nature of its surface. Similarly, Kaufman (*2*) found that oil adhered more tenaciously to the low-energy surfaces of polymers, such as Teflon and polypropylene, than to the high-energy surfaces of a solid such as glass. Chieu et al. (*3*) have reported that polyester fiber (and/or felt) is more efficient than glass wool, glass mats, sand, or polypropylene belts in removing oil from oily wastewater.

The tightly woven consistency and subsequent clogging of the filter cartridges made it necessary to fabricate a larger, more practical filtering unit for use with the ERLN bioassay system. Thus, a wooden, rectangular filter box (1.21 m long × 42 cm wide × 50 cm high) was designed to receive the bioassay effluent. The box was compartmentalized by a series of five baffles that force the incoming oily seawater over and under adjacent baffles, thus maximizing its contact with the filter material.

Table I. Filtering Efficiencies of Cartridge-Type Fiber Filters

Time after start of expt (h)	Acrylic fiber				Viscose rayon fiber				Glass fiber			
	Hydrocarbon concn (ppm)			Flow rate[a] (L/min)	Hydrocarbon concn (ppm)			Flow rate[a] (L/min)	Hydrocarbon concn (ppm)			Flow rate[a] (L/min)
	Input	Discharge	% Eff		Input	Discharge	% Eff		Input	Discharge	% Eff	
1	16.7	0.5	97	2	13.3	2.4	82	2.5	14.2	6.0	58	3.6
2	11.8	0.7	94	2	12.7	1.8	86	2.8	13.6	5.9	57	3.4
3.5	12.4	0.6	95	1	14.4	4.2	71	2.8	12.6	7.3	42	2.5
6.5	11.2	0.8	93	0.8	15.8	4.4	72	2.0	14.7	12.0	18	2.2

[a] Flow rate of effluent leaving cartridge. Note: The initial flow rate of seawater entering the cartridge = 4 L/min.

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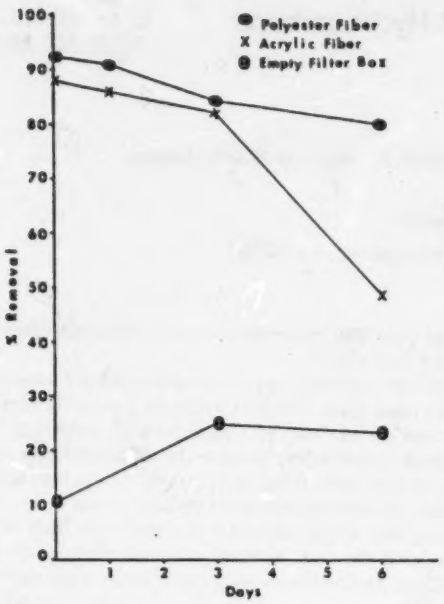

Figure 1. Filtering efficiencies of polyester and acrylic fibers in baffled filter box

Input to box averaged 26 L min^{-1} of seawater with mean concentration of 17.3 ppm dissolved plus dispersed hydrocarbons

Materials tested in the filter box included acrylic, polyester, and glass fibers; polyester fibers with activated charcoal in the last compartment of the box; polyurethane foam; and cotton staple. Before each test, the compartments of the filter box were loosely packed with filter material (approximately 0.1–0.2 kg) so as to not retard the flow of seawater through the box. Concentrations of soluble and dispersed hydrocarbons in the effluent before and after filtration were determined by infrared spectrophotometric analysis.

The filter box, without filter material in it, is capable of collecting up to 25% of the oil, leaving about 15 ppm in the final effluent. This is a result of the settling of oil laden particles to the bottom of the box and the gradual accumulation of insoluble oil droplets near the surface in each of the compartments.

Removal of oil by glass fibers and polyurethane foam was unsatisfactory since extensive clumping of these materials allowed the effluent to channel through the filter box essentially unfiltered. Similarly, removal of oil by cotton ranged from only 15.5 to 25.7%, representing no improvement over the efficiency of an empty filter box. This is in contrast to the study by Johnson et al. (*4*) who reported that for removing crude oil from seawater, natural unscoured cotton was superior to polyester, acrylic, nylon, polypropylene, cellulose acetate, cellulose triacetate, viscose, rayon, and wool.

Figure 1 reveals the filtering efficiencies of the remaining materials used during the experiments. In some cases, the direct comparison of percent efficiencies between time periods or filter materials is difficult due to the variation in the hydrocarbon concentration of the effluent as it entered the filter box. Yet, it is evident that the acrylic (Monsanto Acrylan, 3.0 denier) and polyester (Fairfield Polyfil, 3–6 denier) fibers, both of which originate from a polymer base, had comparably high filtering efficiencies during the first three days of the experiment. Acrylic fibers reduced the hydrocarbon level in the effluent from 9.2 to 1.1 ppm within the first hour of operation; from 10.5 to 1.4 ppm after one day; and from 20.3 to 3.6 ppm at the end of three days. Polyester fibers reduced the level from 18.4 to 1.6 ppm within the first hour; from 21.2 to 2.0 ppm after one day; and from 18.0 to 2.9 ppm at the end of three days. After three days the acrylic fibers tended to clump more than the polyester fibers, thus contributing to a noticeable decrease in their efficiency. By the end of six days of operation, the acrylic fibers reduced the hydrocarbon level from 14.0 to 7.2 ppm, whereas the polyester fibers reduced the level from 20.1 to 4.0 ppm. Replacing the polyester fiber with activated charcoal in the final compartment of the filter box did not increase the filtering efficiency of the filter unit. On the contrary, the charcoal seriously retarded the flow, causing water to back up in the compartments and flow over the tops of the baffles, thus bypassing filtration.

Conclusions

Our data indicate that the use of polymer-based fibers provides an efficient method of removing dissolved and dispersed oil from a bioassay effluent. Further testing with acrylic fibers has revealed that if the fibers are changed after 48 h of use, the concentration of hydrocarbons in the bioassay effluent can be reduced from an average of 17 to approximately 1 ppm.

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